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25th June, 1955

Wind Finding Trials of Radar A. A. No. 3 Mk. V11 (Second Series)

by

C. V. Else
(Meteorological Office)

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(1) Introduction

Since the publication of M.R.P. 672, considerable work has been done on the use of Radar A.A. No.3 Mk.7 as an instrument for wind measurement, and it appeared desirable that a further series of comparison flights should be made to re-assess its usefulness, and to obtain information on its performance at longer ranges. To this end a series of nine flights was made comparing readings taken simultaneously from both the Radar A.A. No.3 Mk.2/4 and Radar A.A. No.3 Mk.7 equipments situated at Stanmore.

As a result of these flights some 500 sets of readings were obtained at slant ranges up to about 66,000 yd. From these readings results were calculated for means, mean deviations and R.M.S. deviations of range, azimuth and elevation for individual flights, and for all flights taken together, over the range scales 0-36,000 yd. and 30,000-66,000 yd. The scale change was actually made between 31,000 yd. and 32,000 yd. These results are reproduced in the tables at the end of the report.

(2) Method of Test

The trial flights were made at the beginning of February, 1955. Mesh type corner reflectors were used, being followed by the two equipments simultaneously. Both sets were set up, and adjusted, normally at the beginning of each day's flights, and the settings were checked, and where necessary adjusted, before each subsequent flight.

The G.L.7 (Radar A.A. No.3 Mk.7) was put on target by using automatic scan in azimuth, and manual control of elevation. The signals were fed to the range display via a delay line equivalent to 1,150 yd. of range, which enabled the signal to be observed emerging through the transmitter echo. The signal is normally located at about 600 yd. range with this method, and the set can be "locked-on" at a range of about 950 yd. When the equipment is locked-on, the delay line is switched out of use so that correct ranges are indicated by the ranging magslip indicators. The range tube is still used for locating the target as a satisfactory combination of P.P.I. control settings has not yet been found for displaying the target clearly at these short ranges.

Information concerning the G.L.7 readings was taken from the G.L.7 output socket, and fed to a braked magslip box operating in the G.L.3 (Radar A.A. No.3 Mk.2/4) cabin. This type of magslip box has been devised to allow virtually instantaneous halting of the magslip pointers when readings are required. It eliminates any errors due to inertia of the moving parts of the magslips, and permits the readings to be held until just before the next set is due, if necessary. Before the trials started checks were made to ensure that the readings at the braked magslip box and those inside the G.L.7 were the same at various readings of range, azimuth and elevation. No discrepancies were found.

/During

During these tests the G.L.3 equipment was fitted with the recently developed Head Amplifier Mk.2, which improves signal to noise ratio at long ranges, and with the Error Sensing Unit, which improves discrimination against noise at long ranges.

Four operators were employed throughout the trials. Three of these were in the G.L.3, and the fourth in the G.L.7. Of the operators in the G.L.3, one operated range, a second azimuth and elevation, and the third recorded all readings from both sets, each minute. The operator in the G.L.7 locked the set on, and then remained on watch and informed the recorder in the G.L.3 if anything untoward occurred. He also made the necessary scale changes in the G.L.7 at the appropriate time.

Readings were recorded each minute to the nearest 10 yd. and 0.1°. Intermediate readings of azimuth and elevation were thrown to the nearest odd tenth.

(3) Technical Remarks

Since M.R.P. 672 was written, a reassessment of methods of range extension led to the conclusion that a normal type of time delay scale extension was possible since the automatic following circuits work by cancelling a modulation signal imposed upon the returned echoes when the set is "off-target". The cancellation of this signal is not dependent upon a knowledge of its amplitude and phase at the instant of transmitter pulsing, as had been previously supposed. The construction of a scale trebler for use with the G.L.7 equipment was therefore undertaken. As a result of preliminary trials it was apparent that the G.L.7 requires a trebler unit of considerably greater stability than the G.L.3. This is because any drift is equivalent, to the automatic ranging circuits, to adding algebraically to the range rate of the target, the range rate equivalent to the drift. For meteorological purposes the servo system is adjusted to work with relatively low range rates, and drift in the trebler unit may increase these rates to a point at which the set ceases to follow (when the target is already moving at speeds near the maximum follow rate). For the same reason the trebler unit must be kept free of any small, sudden, variations in its delay time, as these would be equivalent to short bursts of very high range rates. The G.L.7 also requires synchronising pulses of one half microsecond duration, which are negative going, and delivered from a low impedance source. These considerations lead to a scale trebler unit which is rather more complicated than the one at present in use in the G.L.3 equipments. The size of the unit, is, however, no greater, owing to the use of modern components and techniques.

To aid changing range scale, a form of semi-automatic range changing has been developed for use with the G.L.7 equipment. When the echo nears a given range, towards the end of the scale, a key is depressed. The scale trebler then steps in a delay of 30,000 yd., and the strobe spot is automatically wound back by 30,000 yd. During this operation, which takes about ten seconds, the follow rates for azimuth and elevation, which existed immediately prior to the scale change, are maintained by a "follow-through" circuit. As soon as the range potentiometer has wound back, automatic following is again resumed. If the range rate at the time of scale change is high it is possible for the ranging to fall out of lock. In such cases the range may be brought on again manually, and automatic following then resumed. This has been facilitated by modifying the manual ranging generator so that it now gives a smaller output than previously. Hence it is now necessary to turn the handle more rapidly in order to follow at any given rate. This control was previously very coarse.

All the auto-follow circuits have been adjusted for best results with the low rates of follow to be expected with meteorological targets. The performance of these circuits is fairly good with weak yet steady echoes, but the set is prone to lose the target with a beating signal. The set has followed to about 80,000 yd. on several occasions, but this ability depends largely on the character of the signal.

/As

As the signal becomes weaker, and relatively long fades occur, the servo systems idle and the set drifts off target. As a result the amount of drift, or hunting, in the information output becomes alarmingly large. With fades lasting for several seconds the set may exhibit drifting up to about 4° off target. This drifting is always in the direction in which the servos were last correcting, and is due to residual magnetism effects in the amplidyne system which cause the servos to continue to idle in the direction of last error signal. From this point of view a change to a metadyne system, which is dead-beat, would be advantageous for meteorological purposes. This, however, would be a major modification and might prove impracticable from an engineering point of view. This effect also causes ranging errors, which are normally in a positive direction as range is usually increasing.

The braked magslip system affords an excellent method of extracting the readings from the G.L.7. It may be used at relatively large distances from the equipment, and since control of the brakes is available to the operator noting down the readings, the readings may be "held" until just prior to the next reading, if this is necessary. This method also obviates the dangers of erroneous readings, due to inertia of the moving parts, which can occur if the excitation voltage only is cut off. Braking is almost instantaneous (a lag of a few milliseconds), and once the brake is applied the reading is locked against quite large torques. The "flasher" unit developed at R.R.D.E. was investigated for this purpose, but was not found suitable as the decay time of the phosphor was too short to allow readings to be taken accurately.

Due to the high P.R.F. of the G.L.7 the range of (about) 100,000 yd. represents the limit to which the set can be made to follow, since, by the time the time-bases have re-set themselves, the next transmitter pulse is due to be transmitted.

This G.L.7 is a very old one, and many modifications have been issued, and improvements made, since it was manufactured. A number of modifications has been obtained and incorporated, but it is felt that the performance of this set must inevitably be considerably worse than a more recent one. One point of importance is that recent G.L.7 equipments are being fitted with a new type of head amplifier, which improves the signal to noise ratio by about 6db. A set fitted with this type of head amplifier would probably follow to 96,000 yd. regularly.

During the past two years the G.L.7 equipment has been run for a fairly large number of hours, and considerable experience has been gained concerning maintenance and reliability. When first brought into regular use the failure rate of components was excessively high, and this was investigated. The cause appeared to be overheating, and the refrigeration system was suspected. This was overhauled by an Army team who reported that it was considerably out of adjustment. After the overhaul it was possible to keep the cabin cooler, and the incidence of faults was much reduced.

Two or three units have shown themselves to be regular offenders for failures. One of these is the negative 5,000 volt supply, which regularly blows fuses for no apparent reason, and another is the automatic frequency control unit, which <u>should</u> maintain the tuning of the local oscillator Klystron against drifting. The range "putting-on" potentiometer has also been a source of trouble, causing "creeping" of the measured range to a stationary object by up to 500 yd. in 30 min.

Considerable trouble was experienced initially with the main I.F. strip, which would not hold its tuning. Screening of certain wiring, and the fitting of a screening base plate, cured this trouble. The motor oscillator circuits have also given a little trouble, including insulation breakdown in the oscillator output transformer. This put the set out of action for nearly six months whilst replacements were obtained.

/Faults

Faults are fairly easy to clear, once located, owing to the rack method of mounting all units; and extension leads are available for testing purposes. There is a fairly large selection of metering and monitoring points, which assists in fault location, and we understand that R.R.E. are developing a built-in type of performance measuring equipment.

A serious disadvantage of this equipment is the height of the cabin, which makes working cramped and uncomfortable for everyone except pigmies of less than about 4 ft. 6 in. tall.

Since it is only necessary for one person to remain in the cabin of the G.L.7 equipment while it is operating, there is a saving of one person during a flight, providing that readings can be taken by one of the persons in the radiosonde office. If a separate person in required to note the readings each minute then there is no saving of personnel over those needed when a G.L.3 equipment is used.

(4) Results

A summary of the results obtained is given in the tables attached. These indicate, in general, a high standard of observations. No smoothing has been made to these results; only obvious reading errors of thousands of yards or tens of degrees have been corrected. The results therefore include deviations, due to drifting on weak signals, of up to 4°. In practice, a large proportion of these deviations would be smoothed out during the plotting operations.

The range results show a relative error which starts in one direction, passes through zero and then increases in the other direction. The probable cause of this is slight differences in the frequencies of the two calibrating crystals, which would cause a percentage error varying with range. There is also a systematic error which appears on the second range, which is probably due to slight relative errors in setting up the two scale treblers. At long ranges the G.L.7 tends to read higher than the G.L.3 which, as stated above, is probably due to idling effects in the range servo system on a fading echo.

A comparison with the results given in M.R.P. 672 shows that the mean deviation of the present flights is about twice as large as that given for the original trials. This is because the mean deviation for the present series of flights includes a term due to the relative drift of the two ranging systems. The true mean deviation is considerably smaller than that given, and probably compares favourably with the original value. The value of the mean deviation given for the second scale results is also affected by this relative drift, and its true value will be somewhat smaller than that shown.

The mean differences in range for the two scales of flight No. 8 show a value for the second scale which is more positive than that for the first scale. This is the reverse of the results obtained in all the other flights. The effect is believed to be due to slight errors in setting up the two scale treblers.

The azimuth and elevation results show systematic errors of a few tenths of a degree, which would be corrected before the set was brought into routine use at a station. Unfortunately, at Stanmore, there is difficulty in finding suitable objects to use for setting the equipments up.

The mean deviations obtained for azimuth and elevation for the first scale compare with those given in M.R.P. 672. The azimuth mean deviations are, in fact, identical, whilst that for elevation from the present flights is $.05^{\circ}$ larger.

A comparison of the mean differences of azimuth and elevation with those from M.R.P. 672 shows the azimuth result to be now in a negative direction and about three times larger than previously, whilst the elevation result is still positive but only about one-third the magnitude of the previous result.

/The

The last three flights show an increased difference of azimuth mean of 0.3°, for which no explanation can be found. This also occurred during the 1951 flights (vide M.R.P. 672).

The rates of change of the parameters measured during these flights were average. Range rates were of the order of 1,500 yd. per min., which was about twice the rates obtained in 1951. The azimuth rates varied from almost nil to 12° per min., and were on the whole considerably less than the 1951 rates of change. Elevation showed rates of the same order as azimuth, and a comparison with the 1951 results shows that there is little difference between the rates obtained on the two occasions.

With regard to the maximum deviations, it will be seen by comparison with M.R.P. 672 that the first scale deviations for the present series of flights show a positive value much in accordance with the previous results, but the negative value is considerably greater. This is caused by the drift between the two range scales. This drift has therefore developed since 1951, and is almost certainly due to ageing of the master calibrating crystals. On the second scale the value of the negative deviations becomes very large, value of more than 1,000 yd. being recorded. These large values are partly due to the relative drift already mentioned, and partly due to drifting caused by fading echoes.

The values obtained for azimuth and elevation on the first scale are very much in accordance with the values obtained previously: an occasional large figure in the present tests being caused either by a fade or by interfering aircraft echoes. As might be expected, the values for the second scale are somewhat larger, being the result of echo fading at long ranges.

(5) Conclusions

The radar A.A. No. 3 Mk. 7 equipment is capable of producing wind information of the same order of accuracy as the present G.L.3 equipment at slant ranges up to about 40,000 yd. At longer ranges fading echoes produce considerable drifting in the information outputs, but the intervention of an intelligent interpreter of the information can still produce wind information of a high order.

These experiments have been made with a very old set, and a modern equipment might be expected to have a considerably better performance, together with a consequent improvement in the accuracy of the information output at longer ranges.

Although this equipment is considerably more complicated than the G.L.3 equipment servicing is easier due to the form of construction and the provision of metering and monitoring points.

The fault rate of the equipment depends upon the efficiency of the refrigerating system, which must be kept fully serviceable. When this unit is operating at full efficiency it is doubtful if the fault rate is any higher than that of a G.L.3 equipment.

TABLE 1 RESULTS G.L.3 - G.L.7 SCALE 1 (0-32,000 yd.)

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	RANGE				
		MEAN YD.	MEAN DEVIATION YD.	R.M.S. DEVIATION YD.	MAX. DEVIATION YD.	APPROX. MAX. RATE OF CHANGE YD./MIN.
1	21	+ 45	46	72	+160; -210	1600
2	22	- 70	42	49	+ 0; -170	2400
3	26	-140	53	74	+ 60; -270	1800
4	54	- 75	50	60	+ 20; -220	1100
5	54	-112	63	71	+ 30; -240	1000
6	57	- 34	35	42	+ 70; -130	2800
7	31	- 49	42	49	+ 40; -140	2000
8	26	+ 29	19	25	+130; - 50	1500
9	27	+ 54	27	37	+ 80; - 30	1600
MEAN		- 39	42	56		

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	AZIMUTH				
		MEAN °	MEAN DEVIATION °	R.M.S. DEVIATION °	MAX. DEVIATION °	APPROX. MAX. RATE OF CHANGE °/MIN.
1	21	-0.40	0.16	0.23	+0.0; -0.5	8
2	22	-0.30	0.06	0.10	+0.0; -0.5	2
3	26	-0.30	0.10	0.14	+0.0; -0.8	3
4	54	-0.30	0.13	0.17	+0.2; -0.7	9
5	54	-0.30	0.16	0.27	+0.9; -0.6	12
6	57	-0.20	0.13	0.18	+0.3; -0.6	9
7	31	-0.70	0.11	0.18	+0.0; -1.2	2
8	26	-0.60	0.08	0.10	+0.0; -0.8	3.5
9	27	-0.60	0.06	0.11	+0.0; -0.8	2.5
MEAN		-0.41	0.11	0.18		

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	ELEVATION				
		MEAN °	MEAN DEVIATION °	R.M.S. DEVIATION °	MAX. DEVIATION °	APPROX. MAX. RATE OF CHANGE °/MIN.
1	21	+0.40	0.15	0.20	+0.8; -0.3	5
2	22	+0.10	0.12	0.16	+0.4; -0.3	2
3	26	+0.20	0.06	0.09	+0.4; -0.0	2.5
4	54	+0.10	0.12	0.16	+0.5; -0.3	3
5	54	0.00	0.20	0.33	+0.5; -1.9	4
6	57	+0.10	0.15	0.19	+0.7; -0.2	4
7	31	0.00	0.13	0.17	+0.3; -0.3	2
8	26	-0.10	0.11	0.14	+0.2; -0.3	2.5
9	27	0.00	0.10	0.13	+0.2; -0.2	1
MEAN		+0.07	0.13	0.20		

TABLE 2 RESULTS G.L.3 - G.L.7 SCALE 2 (32,000-66,000 yd.)

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	RANGE				
		MEAN YD.	MEAN DEVIATION YD.	R.M.S. DEVIATION YD.	MAX. DEVIATION YD.	APPROX. MAX. RATE OF CHANGE YD./MIN.
1	38	-165	104	127	+ 10; - 360	1400
2	30	-710	250	295	+ 0; - 1,190	1700
3	35	-700	46	101	+ 0; - 1,040	1000
4	12	-251	47	57	+ 0; - 340	500
5			NO RESULTS			
6			NO RESULTS			
7	30	-590	73	90	+ 0; - 780	1000
8	20	+268	90	114	+110; - 110	1100
9	37	+ 17	32	45	+510; - 10	1000
MEAN		-307	92	146		

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	AZIMUTH				
		MEAN °	MEAN DEVIATION °	R.M.S. DEVIATION °	MAX. DEVIATION °	APPROX. MAX. RATE OF CHANGE °/MIN.
1	38	-0.20	0.23	0.46	+2.2; - 1.0	1
2	30	-0.30	0.17	0.22	+0.0; - 0.8	0.5
3	35	-0.30	0.38	0.80	+0.1; - 1.3	1
4	12	-0.60	0.20	0.36	+0.0; - 1.5	2
5			NO RESULTS			
6			NO RESULTS			
7	30	-0.60	0.12	0.19	+0.0; - 1.0	0.5
8	20	-0.50	0.17	0.23	+0.0; - 0.9	1
9	37	-0.60	0.14	0.18	+0.0; - 1.1	0.5
MEAN		-0.44	0.21	0.43		

FLIGHT NUMBER	NUMBER OF OBSERVATIONS	ELEVATION				
		MEAN °	MEAN DEVIATION °	R.M.S. DEVIATION °	MAX. DEVIATION °	APPROX. MAX. RATE OF CHANGE °/MIN.
1	38	+0.40	0.18	0.30	+1.1; - 1.1	1
2	30	+0.20	0.13	0.21	+0.6; - 0.6	1
3	35	+0.20	0.13	0.20	+0.8; - 0.4	1.5
4	12	+0.30	0.51	0.84	+2.8; - 0.7	1.5
5			NO RESULTS			
6			NO RESULTS			
7	30	-0.10	0.25	0.43	+0.4; - 2.1	2
8	20	+0.10	0.28	0.34	+0.6; - 0.3	1.5
9	37	0.00	0.14	0.21	+1.1; - 0.6	1.5
MEAN		+0.16	0.23	0.37		